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FOREST VEGETATION AS A SOURCE OF BIOGENIC AND ORGANIC SUBSTANCE--ETC(U)
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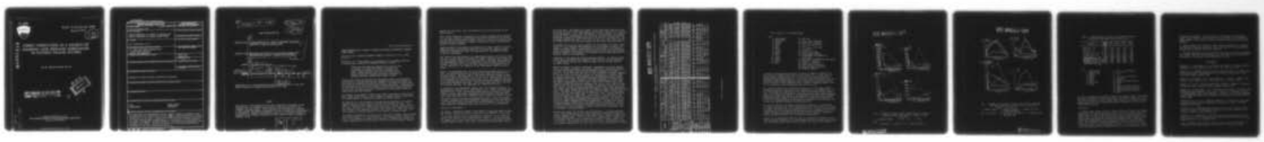

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# FOREST VEGETATION AS A SOURCE OF BIOGENIC AND ORGANIC SUBSTANCES IN NATURAL INLAND WATERS

Yu.G. Maystrenko et al



CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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The experiments for determination of the rate of biogenic and organic matter isolation from the flooded wood (willow, poplar, maple and pine) and of their accumulation in the water of basins showed that the above-mentioned leaf-bearing trees create greater concentrations of these matters in water especially of organic and ammonium nitrogen phosphorus, carbohydrates and aminoacids than coniferous ones (pine). The data obtained can be used when predicting the conditions of new and existing water basins.



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# FOREST VEGETATION AS A SOURCE OF BIOGENIC AND ORGANIC SUBSTANCES IN NATURAL INLAND WATERS

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[Article by Yu. G. Maystrenko, A. I. Denisova and G. A. Yenaki, Institute of Hydrobiology, Ukrainian SSR Academy of Sciences, Kiev]

[Text] Data were obtained concerning the relative rate of release of biogenic and organic substances from flooded forest vegetation and their accumulation in water. These materials can be used in predicting the regime of gases and biogenic and organic substances in existing and newly formed inland bodies of water.

At the present stage of executing the wide-ranging plans of hydrotechnical construction in the USSR and given the demands of the national economy for pure water for technical and household purposes, clarifying the role of factors responsible for water quality takes on added importance. Investigations in this field are vital also in setting up scientifically sound predictions that take into account all sources influencing the hydrochemical regime of inland waters and water quality.

The forming of the regime of biogenic and organic substances in existing and newly formed inland bodies of water depends on numerous factors; among these the various species of vegetation are among the primary factors.

The question as to the influence of flooded forest vegetation on the hydrochemical regime of inland waters formed has been studied the least. In a number of investigations (Kabanov and Sologub, 1955; Miterev, Kibal'chich et al., 1955; Drachev et al., 1957; Miterev and Belova, 1957; Kibal'chich et al., 1960; Drachev, 1961; Bekasova and Konin, 1962; Slack Keith, 1964) only noted the influence of flooded vegetation on the quality of reservoir water.

Of undoubted interest are the works of soil scientists (Kravkov, 1908 and 1938; Mina, 1955; Remezov et al., 1959; Remezov, 1962; Kononova, 1963) showing the role of plant remains in forming soil humus and in accumulating biogenic and organic substances in the soil waters of forest litter and streams. However,

granted all their value, these investigations do not bear directly on the problem raised.

Still, forest vegetation, containing 0.1-10 percent proteins (by dry weight), 15-50 percent cellulose, hemicelluloses and soluble carbohydrates 10-30 percent and lignin 10-30 percent (Kononova, 1963), can serve as a constant source supplying the water medium with organic substances and their mineralization products--biogenic elements.

Complex processes of biochemical transformation of organic remains of forest vegetation play a particularly large role in forming the regime of inland waters with retarded flow, where the significance of intra-body processes is hard to overestimate.

This report gives some findings of an experimental study of the rate of incursion into the water medium of organic and biogenic substances from trees that had been flooded; willow, poplar, maple and pine. The study was conducted in the hydrochemistry division of the Institute of Hydrobiology, Ukrainian SSR Academy of Sciences and is part of major complexes of investigations on the role of vegetation in the formation of the hydrochemical regime of inland waters.

Method. The experiments were set up in large 30-liter glass vessels, 0.8 m high. The wood was placed on the bottom of the vessel and secured with a porcelain weight. The water level in the vessels was kept constant by adding water from the Kiev Reservoir at the rate of the natural water turnover in the reservoirs of the Dnepr (three times a year). The material was a mixture of branches and wood of adult trees and was selected among the thickets of the Dnepr floodplain near Kiev. Its ratio to water was 1:100. The exposure time was 300 days. The experiment was conducted at 17-23° C.

In the water of the experimental vessels, using the standard techniques in hydrochemistry (Drachev et al., 1960; Semenov et al., 1961a, b; Parnas, 1949; Savchenko et al., 1961), determinations were made of the content of organic carbon, nitrogen, phosphorus, permanganate and bichromate oxidizabilities, color index, free amino acids, reducing sugars, phenols, pH, oxygen, $CO_2$ and the mineral forms of nitrogen and phosphorus--nitrite, nitrate and ammonia nitrogen, suspended and solute phosphates, suspended and solute iron and silicon. Serving as control was water from the Kiev Reservoir in which these constituents were determined during the entire time of the investigation.

## Results of Investigation

Gas regime. Substantial changes in the content of oxygen and carbon dioxide gas in water occurred even by the second day of the exposure: the $O_2$ level in the water compared with the background was reduced by 1.5-1.7 times and the $CO_2$ level rose by 2.4-10 times (Figure 1, Table 1). By the tenth day, the oxygen level in all vessels fell to analytical zero and during the next 75 days remained closed to this limit in the vessels storing maple, poplar

and willow wood. The highest $CO_2$ content (12-36 times higher than the starting value) was noted in the same vessels by the end of the first 10-day period of the experiments. Later, some improvement in the gas regime in all vessels, especially those containing pine, set in only by the tenth month of exposure: saturation of water with oxygen approached 40-50 percent (3-5 mg/liter). The pH changed substantially only in the first ten days, and then slight fluctuations were noted in its value with respect to the initial value (see Table 1).

The dynamics of $O_2$ and $CO_2$ agrees closely with the dynamics of organic carbon (Figure 2); this indicates the dependence of the gas regime of water on its content of organic matter. Some deviations in the values of the oxygen and carbon dioxide gas concentrations from the organic matter level are evidently linked to changes in the quality of the organic matter entering the water at different times in the experiments.

Comparison of the oxygen and carbon dioxide gas dynamics in vessels storing willow, maple, poplar and pine suggests a more drawn-out adverse influence of organic matter leached from willow and maple wood on the gas regime in the body of water.

Regime of biogenic and organic substances. Analogously to the gas composition in the water of vessels, even by the second day of exposure the content of organic and biogenic substances had materially changed (see Figure 2, Table 1). By the tenth day, the rate of their accumulation reached a maximum. By the end of the first ten-day period, the concentration of mineral forms of nitrogen rose by 4-77 times compared with the background value, organic nitrogen--by 8-26 times, nitrogen of free amino acids--by 4-25 times, reducing sugars--by 3-7 times, phosphorus of solute phosphates--by 19-160 times and organic substances--by 3.3-12 times. Later, with a steady rise in the content of organic and biogenic substances, the rate of their entry into the water slowed. By the end of the fifth month of exposure, the content of mineral forms of nitrogen exceeded background values by 7-122 times, phosphorus --by 70-248 times, organic matter--by 7-15 times and organic nitrogen--by 13-30 times. The amount of nitrogen of free amino acids in vessels storing maple and pine was 5-6 times higher than in the control, and in vessels containing willow and poplar--1.5 times lower. At the start of the sixth month, the intake of organic and biogenic substances in water declined. By the 300th day, their concentrations exceeded the background values by 2-150 times (due mainly to organic compounds and mineral phosphorus). Gradually the vessels accumulated stable organic matter and mineral forms of phosphorus. Mineral nitrogen evidently was partially utilized by the plankton and bacteria; but in the main, it left the turnover, probably owing to the intensively occurring processes of denitrification.

From the data given (see Figures 1 and 2 and Table 1), it follows that even in the first ten-day period, the water accumulates biologically accessible organic compounds with a narrow C:N ratio and sizable amounts of amine nitrogen and reducing sugars. The C:N ratio here is reduced from 17 (control) to 5 (experiment) and the ratio of amino acid nitrogen to organic carbon rose to 3.2 times. Most constant was the content of labile, biochemically accessible organic compounds (the C:N ratio was 4-6) over the entire period of study

Table 1. Content of Gases, Biogenic and Organic Substances in Experimental Vessels Containing Willow, Poplar, Maple and Pine

| (1) Ингредиенты | (2) Фон | (3) Ива, (5) Дни: (8) 2-д | (9) 10-д | (10) 75-д | (11) 150-д | (12) 240-д | (13) 300-д | (4) Тополь, (5) Дни: (8) 2-д | (9) 10-д | (10) 75-д | (11) 150-д | (12) 240-д | (13) 300-д | (2) Фон |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7,7 | 6,9 | 7,6 | 7,4 | 7,4 | 7,72 | 7,80 | 6,9 | 7,7 | 7,4 | [illegible] | 7,78 | 7,50 | 7,7 |
| $CO_2$, мг/л (16) | 4,4 | 10,6 | 161,4 | 16,7 | 7,0 | 3,5 | 2,5 | 10,6 | 53,0 | 16,7 | [illegible] | 1,8 | 12,3 | 4,4 |
| $O_2$, мг/л (16) | 11,30 | 6,80 | 0,37 | Нет (15) | 0,37 | 2,81 | 3,50 | 6,81 | Нет (15) | 0,83 | [illegible] | 3,50 | 3,50 | 11,30 |
| Железо общее, мг/л (17) | 0,26 | 0,33 | 0,64 | 0,31 | 0,11 | Нет | 0,068 | 0,32 | 0,79 | 0,33 | [illegible] | Нет (15) | 0,080 | 0,27 |
| Железо раствор., мг/л (18) | 0,25 | 0,26 | 0,36 | 0,22 | 0,09 | Нет | 0,026 | 0,26 | 0,44 | 0,19 | [illegible] | Нет | 0,048 | 0,26 |
| $PO_4'''$ общ., мг P/л | 0,022 | 0,33 | 3,41 | 10,70 | 5,40 | 4,78 | 3,22 | 0,33 | 0,82 | 6,50 | [illegible] | 2,70 | 1,65 | 0,022 |
| (20) » раствор., мг P/л (19) | 0,018 | 0,12 | 2,84 | 6,75 | 5,24 | 4,36 | 2,68 | 0,12 | 0,34 | 4,30 | [illegible] | 2,60 | 1,64 | 0,018 |
| $NO_3'$, мг N/л (21) | 0,028 | 0,010 | 0,386 | 0,318 | 0,620 | 0,276 | 0,200 | 0,010 | 0,276 | 0,408 | [illegible] | 0,340 | 0,408 | 0,028 |
| $NO_2'$, мг N/л (21) | 0,003 | 0,010 | 0,012 | Нет (15) | Нет (15) | 0,002 | 0,007 | 0,010 | 0,030 | [illegible] (15) | [illegible] | 0,003 | 0,025 | 0,003 |
| $NH_4^{\cdot}$, мг N/л (21) | 1,04 | 4,16 | 15,32 | 16,85 | 22,24 | 11,32 | 0,9 | 4,16 | 10,00 | 5,88 | [illegible] | 9,32 | 0,925 | 1,04 |
| (22) Кремний, мг/л | 2,37 | 1,70 | — | 15,00 | 8,74 | 9,16 | 8,55 | 1,70 | — | 15,00 | [illegible] | 6,18 | 9,10 | 2,37 |
| (23) Цветность, град. | 100 | 80 | 110 | 73 | 200 | 115 | 100 | 62 | 40 | 133 | [illegible] | 115 | 107 | 100 |
| (24) Перманганатная окисляемость, мг O/л | 14,7 | 27,2 | 47,6 | 50,4 | 56,4 | 25,6 | 18,0 | 19,7 | 60,6 | 32,8 | [illegible] | 9,4 | 20,8 | 14,7 |
| (25) Бихроматная окисляемость, мг O/л | 46,8 | 100,0 | 113,1 | 282,2 | 268,8 | 89,6 | 77,8 | — | 113,2 | 78,0 | [illegible] | 9,6 | 9,07 | 46,8 |
| (26) Органический C, мг/л | 14,5 | 49,0 | 48,0 | 100,8 | 108,0 | 33,6 | 29,6 | — | 48,0 | 30,0 | [illegible] | 3,6 | 34,0 | 14,5 |
| (27) Органический N, мг/л | 0,84 | 4,6 | 8,5 | 17,3 | 24,0 | 7,7 | 5,24 | — | 11,3 | 10,1 | [illegible] | 8,0 | 7,1 | 0,84 |
| (28) Аминокислоты, мкг N/л | 17,5 | — | 185,8 | — | 8,5 | 37,2 | — | — | 73,6 | — | [illegible] | [illegible] | — | 17,5 |
| (29) Редуцирующие сахара, мг/л | 0,5 | — | 1,7 | — | 1,2 | 1,2 | — | — | 3,7 | — | [illegible] | 1,3 | — | 0,5 |
| (30) Фенолы, мг/л | 0 | — | 0,012 | 0,027 | 0,005 | — | — | — | — | — | [illegible] | — | — | — |

| (1) Ингредиенты | (6) Клен, Дни (5): (8) 2-д | (9) 10-д | (10) 75-д | (11) 150-д | (12) 240-д | (13) 300-д | (2) Фон | (7) Сосна, (5) Дни: (10) 10-д | (14) 45-д | (11) 150-д | (12) 240-д | (13) 300-д |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 7,2 | 6,1 | 7,5 | 7,6 | 7,80 | 7,72 | 7,7 | — | 7,5 | 7,3 | 7,85 | 7,6 |
| $CO_2$, мг/л (16) | 53,4 | 69,5 | 9,7 | 2,6 | 1,8 | 7,9 | 4,5 | — | 14,1 | 7,0 | 1,8 | 14,1 |
| $O_2$, мг/л (16) | 6,30 | Нет (15) | Нет (15) | 0,36 | 2,9 | 5,5 | 7,5 | — | 1,81 | 3,56 | 7,5 | 2,3 |
| Железо общее, мг/л (17) | 0,25 | 0,54 | 0,38 | 0,30 | 0,023 | 0,120 | 0,81 | — | 0,10 | Нет (15) | Нет (15) | 0,080 |
| Железо раствор., мг/л (18) | 0,18 | 0,51 | 0,33 | 0,19 | 0,023 | 0,048 | 0,46 | — | 0,09 | Нет | Нет | 0,070 |
| $PO_4'''$ общ., мг P/л | 0,33 | 2,78 | 10,20 | 4,20 | 4,80 | 2,54 | 0,042 | — | 0,68 | 0,54 | 0,36 | 0,070 |
| (20) » раствор., мг P/л (19) | 0,24 | 2,57 | 6,00 | 3,60 | 4,18 | 2,50 | 0,007 | — | 0,55 | 0,48 | 0,10 | 0,03 |
| $NO_3'$, мг N/л (21) | 0,030 | 0,386 | 0,340 | 0,610 | 0,362 | 0,210 | 0,011 | — | 0,428 | 0,590 | 0,610 | 0,400 |
| $NO_2'$, мг N/л (21) | 0,005 | 0,003 | 0,007 | 0,007 | 0,003 | 0,012 | 0,004 | — | 0,014 | 0,001 | 0,003 | 0,002 |
| $NH_4^{\cdot}$, мг N/л (21) | 1,97 | 11,76 | 7,90 | 16,64 | 9,76 | 0,964 | 1,03 | — | 4,20 | 6,92 | 4,88 | 1,13 |
| (22) Кремний, мг/л | 2,90 | — | 15,00 | 6,86 | 9,16 | 8,55 | 2,65 | — | 4,70 | 4,60 | 7,50 | 10,0 |
| (23) Цветность, град. | 80 | 53 | 133 | 154 | 136 | 125 | 55 | 100 | 100 | 80 | 128 | 125 |
| (24) Перманганатная окисляемость, мг O/л | 29,6 | 45,1 | 52,8 | 56,2 | 21,2 | 19,2 | 10,6 | 14,7 | 30,4 | 52,0 | 23,8 | 21,6 |
| (25) Бихроматная окисляемость, мг O/л | — | 311,1 | 310,2 | 512,0 | 92,0 | 82,0 | 33,0 | 100,0 | 202,0 | 358,4 | 83,6 | 82,2 |
| (26) Органический C, мг/л | — | 183,0 | 150,0 | 192,0 | 36,0 | 31,6 | 9,5 | 50,0 | 100,0 | 134,4 | 33,6 | 48,6 |
| (27) Органический N, мг/л | — | 22,00 | 20,2 | 15,0 | 9,9 | 6,8 | 0,6 | 4,8 | 7,2 | 8,0 | 6,2 | 5,5 |
| (28) Аминокислоты, мкг N/л | — | 422,0 | — | 106,9 | 46,0 | — | 25,3 | — | — | 143,7 | 58,9 | — |
| (29) Редуцирующие сахара, мг/л | — | 2,0 | — | 0,9 | 0,9 | — | 0,5 | — | — | 1,0 | 1,0 | — |
| (30) Фенолы, мг/л | — | — | — | — | — | — | — | — | — | — | — | — |

[Key on following page]

[Key to Table 1, on preceding page]

Key:

1. Constituents
2. Background
3. Willow
4. Poplar
5. Days
6. Maple
7. Pine
8. Second
9. Tenth
10. 75th
11. 150th
12. 240th
13. 300th
15. None
16. mg/liter
17. Iron , total, mg/liter
18. Iron-solute, mg/liter
19. $PO_4'''_{total}$, mg P/liter
20. $PO_4'''_{solute}$, mg P/liter
21. mg N/liter
22. Silicon, mg/liter
23. Color index, degrees
24. Permanganate oxidizability, mg O/liter
25. Bichromate oxidizability, mg O/liter
26. Organic C, mg/liter
27. Organic N, mg/liter
28. Amino acids, mcg N/liter
29. Reducing sugars, mg/liter
30. Phenols, mg/liter

in vessels storing poplar and willow; the ratio of ammonia nitrogen to the total amount of organic matter here was also higher (by 3.5 times) than in vessels containing maple and pine. As the data show, maple and pine--on interacting with water--produce in it relatively higher concentrations of biochemically stable organic compounds than do poplar and willow; this difference is reflected in the higher C:N ratio in vessels containing poplar, from 7.3 to 13, and in vessels containing pine--from 14 to 16.6.

The observed changes in the qualitative composition of the organic matter released by wood into water are in good agreement with the dynamics of $O_2$ and $CO_2$. The intensive accumulation in the first ten-day period of the experiment--in the water of all vessels--of biochemically unstable organic compounds containing a significant amount of carbohydrates, amino acids and cellulose hydrolysis products leads to an abrupt drop in the content of oxygen and to a rise in the concentrations of the products of chemical and biochemical oxidation--$CO_2$, ammonia nitrogen and solute phosphorus.

The various indicators of organic and biogenic substances we recorded must be looked at as the result of two opposing processes: the leaching into water of organic substances and their mineralization. As is clear, in all the cases considered, the first process--leaching and partial metamorphization of the organic compounds--predominates (in any case, during the first 5 months of contact of wood with water) over the latter--mineralization.

Results of our experiments afford an idea of the amounts of biogenic and organic substances released in the spring-summer period by flooded forest plants into the inland waters (Table 2) and also shed some light on the problem of

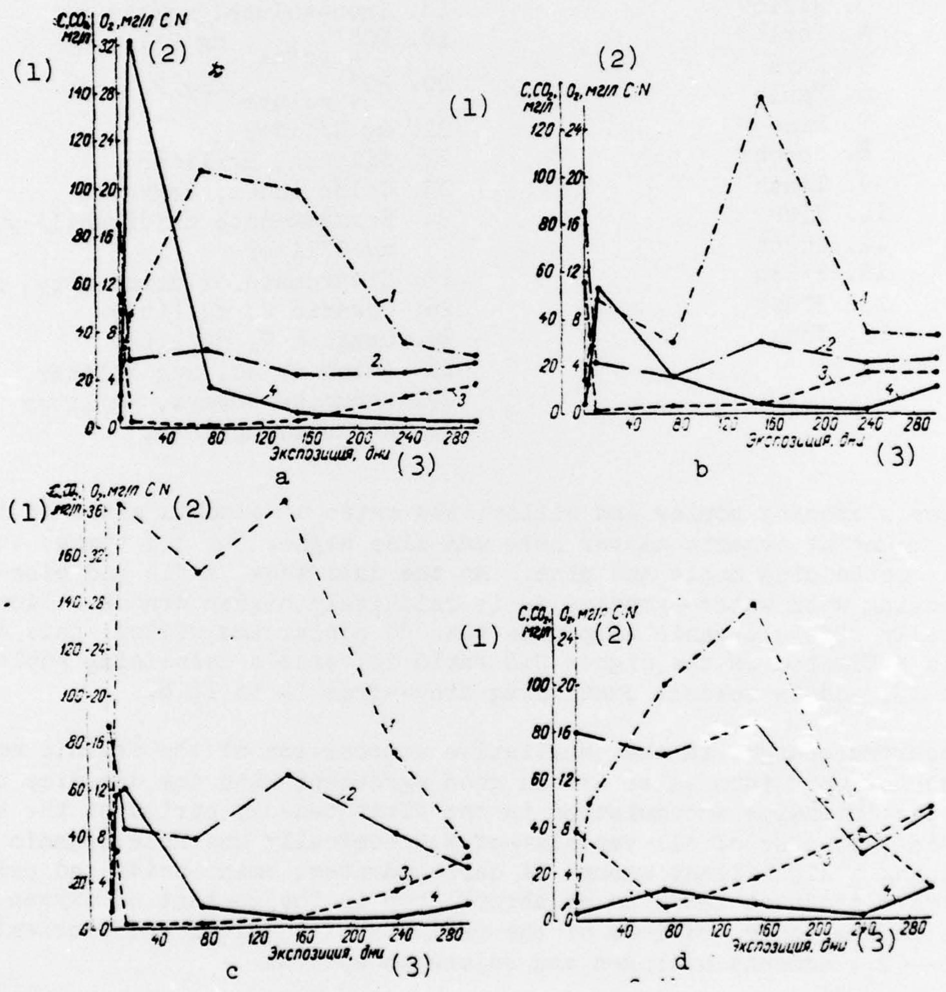


Fig. 1. Dynamics of gases, organic matter and C:N in vessels containing willow (a), poplar (b), maple (c) and pine (d).

1. organic matter  2. C:N  3. $O_2$  4. $CO_2$

Key:

1. mg/liter  2. mg/liter C:N  3. Exposure, days

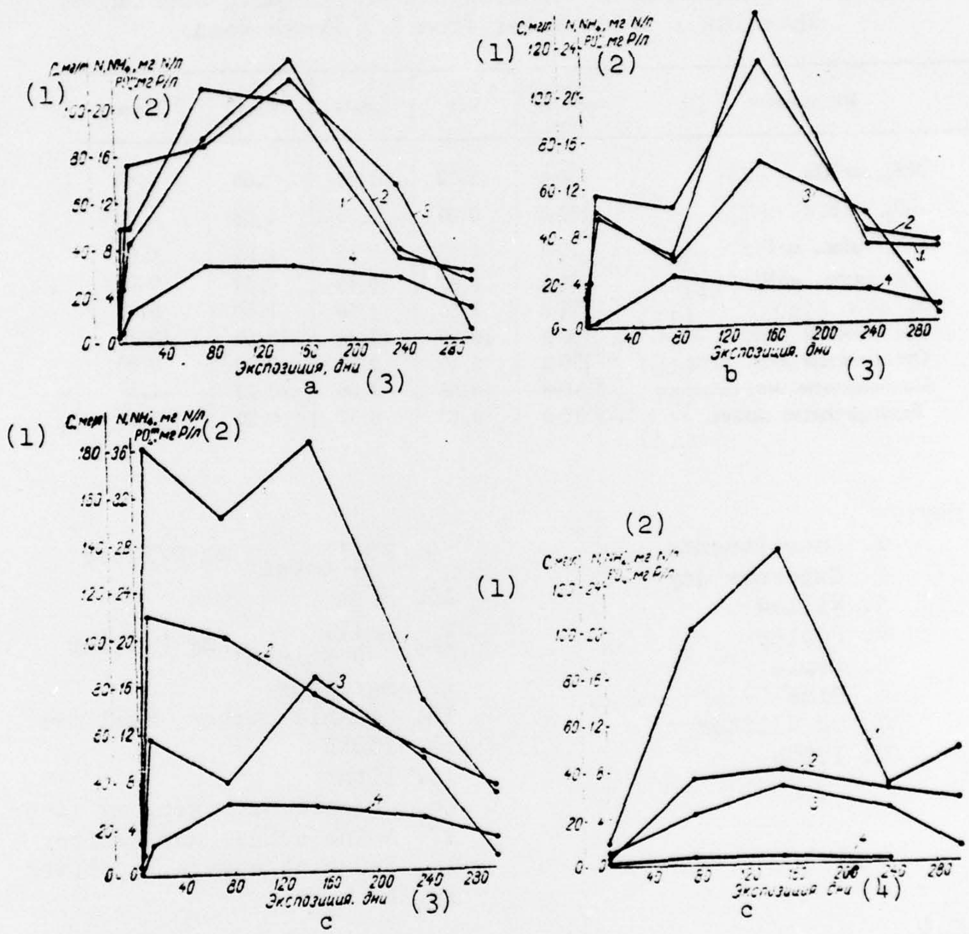


Fig. 2. Dynamics of the entry of organic and biogenic compounds into water during the decay of willow (a), poplar (b), maple (c) and pine (d).

1. organic carbon 2. organic nitrogen 3. ammonia nitrogen 4. mineral phosphorus

Key: 1. mg/liter 2. mg N/liter, mg P/liter 3. exposure, days 4. exposure, days

Table 2. Maximum Amount of Biogenic and Organic Substances Entering 1 liter Water from 1 g Fresh Wood

| Ингредиенты (1) | День экспозиции (2) | (3) Ива | (4) Тополь | (5) Клен | (6) Сосна |
|---|---|---|---|---|---|
| $NH_4^{\cdot}$, мг N/л (7) | (8) 150-й | 2,22 | 1.40 | 1.66 | 0,69 |
| $NO_3'$, мг N/л (7) | 150-й | 0,06 | 0,05 | 0,06 | 0,06 |
| $PO_4'''$ общ., мг P/л (9) | (10) 75-й | 1,07 | 0,65 | 1,02 | 0,07 |
| » раств., мг P/л (11) | 75-й | 0,67 | 0,43 | 0,60 | 0,06 |
| Si, мг/л (12) | 75-й | 1,50 | 1,50 | 1,50 | 0,46 |
| Органический углерод, мг/л (13) | 150-й | 10,88 | 13,44 | 19,20 | 13,40 |
| Органический азот, мг/л (16) | (14) 150-й | 2,40 | 2,25 | 2,20 | 0,80 |
| Аминокислоты, мкг N/л (17) | (15) 10-й | 18.58 | 7,36 | 42,22 | 14.37 |
| Редуцирующие сахара, мг/л (18) | (19) 10-й | 0,17 | 0,37 | 0,20 | 0,10 |

Key:

1. Constituents
2. Exposure day
3. Willow
4. Poplar
5. Maple
6. Pine
7. mg N/liter
8. 150th
9. $PO_4'''$ total, mg P/liter
10. 75th
11. $PO_4'''$ solute, mg P/liter
12. mg/liter
13. Organic carbon, mg/liter
14. 150th
15. 10th
16. Organic nitrogen, mg/liter
17. Amino acids, mcg N/liter
18. Reducing sugars, mg/liter
19. 10th

the role of flooded forest plants in forming the regime of gases and biogenic and organic substances in new inland waters. Knowing the numbers of forest plants in the bed of a reservoir under construction, we can predict the gas regime and the regime of biogenic and organic substances in the first years of the reservoir's use.

## Conclusions

1. Flooded forest plants serve as a constant source of biogenic and organic compounds in the surrounding body of water. When the volume of wood in the body of water is large (1:100), during the first ten (and sometimes even longer) days, the gas regime worsens catastrophically and the water accumulates significant amounts of biochemically unstable organic compounds, in particular, carbohydrates and the hydrolysis products of proteins--amino acids. The content of biogenic substances by the fifth month exceeds the background values by tens and hundreds of times. As a result of the intensively occurring processes of mineralization, the water accumulates ammonia

nitrogen and phosphorus. By the sixth month, the amount of biochemically stable organic compounds increases (with a total decrease in the content of organic matter), the content of biogenic substances drops and the gas regime improves.

2. These deciduous trees produce in water higher concentrations of organic and biogenic substances, especially organic and ammonia nitrogen, phosphorus, reducing sugars and amino acids than does pine.

3. The data recorded on the rate of release of biogenic and organic compounds from flooded trees and their accumulation in water can be used in predicting the regime in existing and newly formed bodies of water.

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